DEVELOPMENT OF PRODUCTION RATE DATABASE FOR SUPERSTRUCTURE BY DIRECT OBSERVATION

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Development of Production Rate Database for Superstructure by Direct Observation

by

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(Mohd Azraf Bin Ramlan)

ABSTRACT

Improving labour productivity is one of the most significant areas that may result in competitive advantage for construction companies. This requires continuous monitoring, documentation and measurement of factors like quantity of work, site conditions, work conditions and crew characteristics. This article introduces a direct productivity measurement based system for documentation and monitoring of construction labour productivity. The system not only provides a user friendly environment for documentation and monitoring of construction labour productivity but also undertakes various statistical analyses. This project develops and analyze of a production rates database for Civil and Structural Engineer by direct observation of superstructure works.

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Mr Nazri	Power Chain Sdn. Bhd.
Mr Nazimmuddin	Perbadaanan Kemajuan Negeri Melaka (PKNM)
Pn Linda	Perbadanan Kemajuan Negeri Selangor (PKNS)

I would also like to extend my appreciation to all my colleagues for their fully support and collaboration. Last but not least, I wish to express my heartfelt appreciation to my parents and family members for their moral support. All contributions have been most meaningful to me and your support gave me the strength to persevere. Thank you very much.

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INTRODUCTION

1.1 Background of Study

In construction, information on activity duration is important in scheduling construction activities on site, in costing the activities or in predicting overall project completion time. Activity duration is computed by dividing the quantity of work involved with the number of resources used and the corresponding production rate (e.g. m3 of concrete poured per hour per hour, tones of steel reinforcement laid per hour, m2 of formwork installed per hour, etc.).

Thus:

$$\text{Production rates (R)} = \frac{\text{Quantity of work (Q)}}{\text{Activity duration (T) x No. of resources (N)}}$$

Quantity of work and number of resources (people or machine) can be quantitatively determined. However, because production rates are greatly affected by various controlled and uncontrolled factors, no specific calculation can be derived to evaluate them. Because of this, their values have all been based on the experience and judgment of the individual construction manager, as well as from previous company records. These values are often subjective and also not freely available to others outside the company. There is therefore a need to elicit and compile such information from the industry, analyze to develop a formal database of "moderated" production rates, which is not only reliable but also accessible by everyone in the industry.

A previous research at Universiti Teknologi Petronas (UTP) has focused on the collection of production rates data for structural works of a building project from industry experts by questionnaire survey.

Direct Observation method describes a direct method to measure, monitor and optimize construction and maintenance project labor productivity. The method described statistical sampling of the work process which made up of steps and activities that take input resources, add value, and produce the completed project.

Sampling from Direct Observation method is a cost-effective way to provide information about the performance of the work process, i.e.,' how' the work is done, and how to do it better. Work sampling complements conventional project management methodology, which typically tracks 'what' work is done.

Sampling provides project managers, supervisors, and the workforce with objective feedback such as the efficiency of the work process (not of individual workers, foreman's job). Analysis of the sampling data allows for prompt removal or reduction of roadblocks, optimizing the construction work process through redesign and innovation.

Work sampling, properly applied, recognizes that productivity results from an optimal work process, i.e. from 'managing smarter,' not from people working harder.

Construction labor productivity is a measure of work process efficiency. It can be defined as the ratio of the value labor produces to the value invested in labor. Productivity increases as needed labor resources are minimized and wasted efforts eliminated from the work process.

1.2 Problem Statement

When individuals estimate the production rates of construction activities in a project, they frequently refer to the past production rates achieved in a similar project. Problems in these estimations are

1) the data represented in historical documents and databases do not provide detailed information depicting the conditions under which the activities were executed (i.e. contextual data) at different zones in a given project and in multiple projects.
2) these databases only tell the duration of works need to be completed, but do not enable estimators to determine the production rate of an activity.
3) not having the production rate and site condition related data represented in an integrated way within one project model results in time consuming manual data integration to access and analyze the data in an integrated way.

As a result, currently, estimators rely on their or other estimators' memory in performing cost estimates. This situation results in individuals estimating the same production rate differently, contributing to underestimation or overestimation of a project, and consequently cost overruns or missing project opportunities due to overbids.

To improve decision making of estimators in construction companies, an integrated project history model is proposed to provide the information required by estimators at different levels of details. By using direct observation, estimators can create an integrated project history model requires

1) identifying requirements of estimators from past projects,
2) determine the production rate of an activity for project competence in a time given by the Owner of the project.
3) enabling capturing of these data in a formal way during construction,
4) identifying what constitutes contextual data required for supporting the analysis of production rates of an activity

1.3 Research Objectives

This project aims to measure and assess the productivity for structural work process by direct observation method to provide useful, (near) real-time information about the process and enable more efficient, safe completion of the work scope so that fewer labor-hours will be expended.

With this aims, the objectives of the research are;

1) To collect data on production rates from the construction site by direct observation
2) To analyze data collected using statistics
3) To compare the data obtained by previous sources

Consistent application of sampling from direct observation over a period of time provides project managers ongoing information about the effectiveness of actions taken to continuously improve the work process. Properly applied, it is effective in getting more construction or maintenance work done with fewer labor-hours, and with greater worker safety and satisfaction.

1.4 Scope of Study

The whole project would start with the knowledge gathering and theoretical studies. First of all, understanding the basic theory on construction productivity and direct observation method for collecting data are very important. Paper works, journals, engineering books or anything relevant to the project are reviewed. The review on the literature relevant to the research topic is important to know this study relates to the information already available and how the finding relates to this project. After understanding the concept and methodology, direct observation can be done at site. Data collected will be analyzed by using statistic for database. Final comparison between data obtained and published sources will determine the outcomes of this project.

Hence, the author optimist that feasibility of this project within the Scope and Time Frame is enough to be covered and completed in the two semester final year study.

CHAPTER 2

LITERATURE REVIEW

The *Concise Oxford Dictionary* (9th edition) defines productivity as: (i) the *capacity to produce*, that is the force behind production itself, (ii) *effectiveness of productive effort* as a measure of how well the resources are utilized and (iii) the *production per unit of effort* (or rate) to measure output of the factors of production over a defined period of time. However, the definition in Davis (1951) – 'the degree to which the power to make or provide good services having exchange value is utilized as measured by the output from the resources utilised' – seems to occupy the 'central ground', incorporating the three main characteristics of the productivity concept, and consequently is adopted as the working definition in this research.

Construction productivity can be calculated in a number of different ways like the ratio between output and work hours or the ratio between work hours and output where; the first one is more commonly used as called 'production rate' (Sönmez and Rowings, 1998). A lot of factors influencing construction productivity such as nature of the industry, the construction client, weather, level of economic development (external factors), management, technology, labour and unions (internal factors). Therefore, it is importance to rectifying this problem and continuous improvement in construction works to minimize waste in terms of labour productivity.

Construction and major maintenance projects are commonly managed and controlled through oversight and coordination. At intervals, progress is tracked against agreed-upon schedules and budgets – which are estimated, based largely on historical performance data. This method may be effective for highlighting when performance is not on track with plans. But it does not show why productivity is lagging or out of control, nor does it support decisions on corrective actions and improvement of the work process (AACE International Recommended Practice, 1994). As such, traditional project control measures do not fully address the objective of improving cost and schedule performance. For meaningful cost and schedule optimization, direct

productivity measurement must be used to complement the indirect, relative control measures that compare performance to the estimate

A new, practical way to ensure customer value is to measure and continuously improve the efficiency of project execution using an existing low-cost technique of work sampling specifically geared to construction work (as specified e.g., in the Association for the Advancement of Cost Engineering International, AACEI Standard Practice RPS 22R-01, "Direct labor productivity measurement as applied on construction and major maintenance projects"). This direct measurement method provides independent project
performance data, un-coupled from budget/schedule estimates and traditional project cost/progress reporting (Power-Gen International Conference Orange County Convention Center, Orlando, FL Nov. 30 – Dec. 2, 2004)

Literature review reveals that there were some previous efforts to automate collection of labor data, including:

1) Construction companies, which have recently begun to utilize new data collection technologies, presented their developments in a conference called Automated Data Collection in Construction (ADCIC) 2000.
2) A conceptual model using Radio Frequency Identification (RFID) technology. According to their concept, the worker's arrival on site and movement between tasks are recorded automatically using RFID technology, but the worker has to record the cost code of the various activities in which he/she was engaged, using a hand-held computer (Jaselskis et al, 1995).
3) A system for labor inputs and materials tracking system, comprised of three modules: (i) a database, which includes the project's plans, (ii) data collection using barcodes and manual inputting and (iii) an analysis module, (Echeverry and Beltran, 1997)

4) The British Research Establishment has presented another approach to labor inputs measurement, using a full time observer(s) and a hand-held computer. This measurement technique uses a human observer(s) who tours the site at regular time intervals and records tasks being undertaken.

Time study includes process of identifying required number of observations through a pilot study: After defining the work and the duration of the observations, it is time to observe the productivity of the crew. At this point, an important question about the required number of observations arises. A pilot study of between 5 to 10 observations then have to be carried out in order to determine the statistically valid number of observations required as shown in Equation below:

$N' = (40(N\Sigma x^2 - (\Sigma x)^2)^5) / \Sigma x)^2$ (Kobu, 1999)

N': Required number of observations within 95% confidence interval.

N: Number of observations during the pilot study.

Xi: Unit output of the related labour (crew) during the i.th observation

Proportions of time devoted by crafts and technicians to the variety of work activities, and the variability of the work process are measured. The application has proven effective on hundreds of construction and maintenance projects, achieving labor cost savings of 20 to 30 percent, and more.

Absolute accuracy of resulting data can be calculated with this formula:

$$A = Z\sqrt{p(1-p)/N} \quad (1)$$

Where:

A = absolute accuracy

Z = number of standard deviations σ (for the 95 percent confidence level, the value of $Z = 2$)

p = the observed percentage, obtained by work sampling

N = the total number of work sampling observations made.

For the studies of development of production database for Civil and Structural engineering works by direct observation, the author will identify the Superstructure items activities such as Column, Floor Beam, Floor Slab, Roof Beam, and Staircase. Then, the studies continue with the investigation about Superstructure main activities;

(i) Cut and install formwork, (ii) Cut, bend and install reinforcement, (iii) Concrete works (iv) Dismantle formwork. Besides that, by referring to the form of 'Production rate database record' (example as Figures shown below), it also shows important data as references;

1) Quantity of man power
2) Location
3) Machineries used
4) Production rate (unit per hour)
5) Remarks

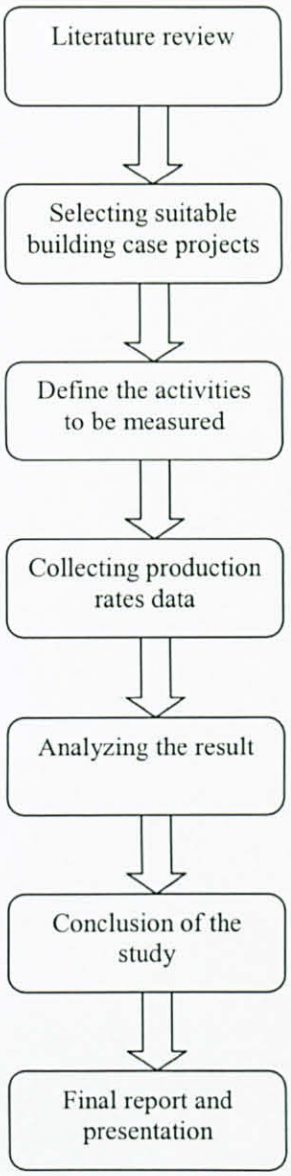
In order to have a further understanding about the production database for Civil and Structural engineering works by direct observation, the author has refers to some of the previous research in journal, books, articles and other relevance references.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

The following are the flow chart of the author project.



The investigation will employ the "observational" method of research methodology involving the following basic tasks:

1) Literature review to acquire basic background knowledge of Lean Construction and previous related research by others
2) Selecting atleast three (3) suitable building case projects, probably in Ipoh, hometown (Melaka) and developing are (Klang Valley)
3) Define the activities involved to be measured
4) Collecting production rates data using stop watch and/or video camera
5) Analyzing the result using statistics
6) Conclusion of the study
7) Final report and presentation

3.2 Data Collection Methodology

Work sampling requires routine data collection by trained construction or maintenance analysts observing the entire workforce on-site (with some exceptions discussed later). Random-walk observation tours must be conducted at randomly selected times during all work periods, excluding periods when no work takes place, such as end-of-shift

Craft activities are manually recorded according to specific activity category classifications, which are pre-defined and may be customized for the specific construction or maintenance project. Covering the entire labor workforce on-site, each worker is counted as one sampling observation.

Before the start of each observation tour, the analyst determines and documents crew size(s), their foreman, and their work area(s) to ensure the entire workforce will be observed. An analyst impersonally observes and records all craft and foreman activity occurring on the project by placing tick marks on a data collection form (such as the "Data Collection Form), and also records the number of craft workers not observed on-site ('un-accounted for').

Using statistical software, the percentage of observations of each activity category is computed. The resulting data shows the overall crew utilization for the period work sampled and may be printed out graphically, e.g., in pie chart format. By applying the proportions of value-added and non-value-added activity to the total labor-hours available, the time spent on each category can be determined. A print-out of a scatter diagram of, e.g., the percentage of productive utilization ('direct work') versus the tour start times, is a practical way to graphically verify randomness and determine variation of the work process. The software will calculate the mean (average) level of productive activity and the standard deviation for the overall process.

Working in support of owner and/or contractor project management, cost management helps identify opportunities to cause improvement and recommend streamlining and/or re-design of the work process, and establishing guidelines for project-specific best practices including:

1. On-going measurement, analysis and optimization of productive labor utilization;
2. Prompt feedback (e.g., no later than end of shift) on work process efficiency;
3. Analysis of process trend and variability data taken over time;
4. Assessment of work process performance vs. baseline and industry benchmarks;
5. Up-front planning and preparation with the objective of most efficient workflow;
6. Updating historical estimating databases for future 'lean' estimating;
7. Regular review and audit of soundness of implementation of this practice.

3.3 Getting Buy-in of Work Sampling

Before starting work sampling, the use of the method must be tell 'sold' to all personnel at all levels of organizations affected, including top management, supervision and, if present, union representatives.

Typically, 15-minute briefings of field supervision and union representatives are effective. Craft workers can be briefed on basic work sampling procedure during hiring-in procedure, e.g. by means of a short, custom-prepared video which ensures consistency of presentation. It is important to explain the impersonal data collection procedure, the activity definitions, and how the sampling results are used to show the efficiency of the work process.

3.4 Planning Implementation of Work Sampling

Tours of the site:

1. Determine desired accuracy of the results and specify the level of confidence, e.g. a relative accuracy of ± 5% at a 95 percent confidence level is practical and usually adequate.
2. Next, determine the required number of observations to achieve the desired accuracy, e.g by using a statistical accuracy look-up table.
3. Based on the anticipated observation tour time to cover the workforce on-site, determine the daily number of work sampling tours needed to achieve the required number of observations.
4. Subsequently, design the work sampling form on which to record the observations.

3.5 Implementing Random Work Sampling

Implementation on construction or maintenance project sites includes the following activities and deliverables:

1. Conduct up-front briefings to ensure management, supervision and workforce buy-in before starting measurement of work activity.
2. Determine which jobs on the site to exclude from the work sampling. It may not be cost effective to observe a small crew working in a remote area, requiring a great deal of travel time to observe. In such case it may be more practical to keep this small number of workers out of the sampling. (Note that the resulting data only reflects actual observations made in work areas included in the sampling).
3. Measure workforce utilization by observation of the entire workforce on-site (except jobs that are excluded because of distance from the main work area).
4. While conducting work sampling observation tours, it is useful to ask the question: "What can be done to improve productive utilization, reduce wasted time, minimize travel, and streamline workflow?"
5. Communicate regularly with field supervision, asking about job locations, manning, existing procedures such as breaks, tool control, safety meetings, and any constraints or interferences.

6. Regularly produce easy-to-read graphic labor utilization reports, e.g. pie charts, trend charts, scatter diagrams.

7. Prepare action recommendations (e.g. an "action item list") to reduce non-value-added activities (avoiding "finger-pointing" or "blaming") for presentation to site project management.

8. Offer and be prepared to facilitate team problem solving with select craft and foreman participation, producing recommendations to management to improve the work process. Include a determination of the cost-benefit of recommended work process improvement opportunities.

9. Review and update historical estimating database with latest data.

10. On request, conduct continuous improvement training workshops.

Supported by top management, improvement of the work process can cause significant labor cost and time savings. And, through communication and emphasis on "working smarter", labor representatives typically respond well to the continuous work process improvement approach that makes working more 'convenient' for the worker.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Project Deliverables

As for defining superstructure activities, the author has summarized the activities in such method of production database record. Figure1 in the Appendix shows the Production Rate Database for Superstructure Activities by Direct Observation record sheet;

4.1.1 Activities to be Measured

'Production rate database record' sheets are thus designed in order to record the productivity that included;

Items:

1) BEAM 1st / 2nd / 3rd / roof) floor
2) COLUMN 1st / 2nd / 3rd / 4th) floor
3) SLAB 1st / 2nd / 3rd) floor
4) STAIRCASE

Activities:

1) Size measurement & Cutting formwork
2) Installing formwork
3) Installing falsework
4) Cutting and bending reinforcement
5) Fabricate reinforcement
6) Installing reinforcement in formwork
    a. Main bar
    b. Links
    c. Loose bar
7) Concrete placement
    a. Skip & Bucket
    b. Pumping
    c. Chute
    d. Curing strength gaining
8) Formwork Dismantling
9) Falsework Dismantling

Common / AlternativeUnit:

1) m2/day
2) Tonnes/day

Other Factors:

1) 1; high severity 2;moderate severity 3; low severity
2) No. of workers
3) Weather
4) Availability of Material and Equipment
5) Location of the Project
6) Site conditions
7) Project complexity
8) Machineries used per day V = vibrator Cm = concrete mixer Bh = backhoe C = crane

4.1.2 Project Details Form

A separate sheet as in Figure 2 of Appendix called Project Details Form is also available to record the following details;

1) Project Tittle
2) Site Location
3) Company (Owner)
4) Civil Works (Contractor)
5) Observer
6) Attached to

4.1.3 Additional Information Form

Work and site management related factors affecting the labour productivity are also presented on 'Additional Information Form' sheets as Figure 3 in the Appendix:

4.2 Findings and Data Gathering/ Data Analysis

4.2.1 Selecting 3 suitable projects

After understand the basic theory on construction productivity and direct observation method for collecting data, the author had done the direct observation and managed to collect the production rates for super structure activities at three sites.

The 3 selected building case projects are from different area in Malaysia which is from Selangor, Melaka and Perak. The details information of the site projects are;

1) PERAK SITE

Project:
Cadangan membina dan menyiapkan satu unit bangunan pusat latihan jahitan pakaian dan pejabat dua tingkat.

Site Location:
Lot 133080 (PA 83928) Mukim Teja, Daerah Kinta, Perak

Company (Owner):
Jabatan Alam Sekitar (JAS)

Civil Works (Contractor):
NRS Associates (Power Chain Sdn. Bhd.)

Aattached to:
Mr Nazri (Site Supervisor) – 017 5760865

2) MELAKA SITE

Project:
Cadangan merekabentuk, membina dan menyiapkan (design and build) pusat akuatik serta lain-lain kerja yang berkaitan.

Site Location:
Kompleks Sukan Hang Jebat, Mukim Paya Rumput, Daerah Melaka Tengah, Melaka.

Company (Owner):
Perbadaanan Kemajuan Negeri Melaka (PKNM)
Mr Nazimmuddin – 019 6678127 (office) 06 2325037

Civil Works (Contractor):
LIMA Corporation Sdn. Bhd.

Attached to:
Mr Arshad B Zaini (Site Supervisor) – 019 3383771

3) KL SITE

Project:
Cadangan membina dan menyiapkan 14 unit rumah banglo berkembar 2 tingkat
No.kontrak : PKNS/BBB/KON-11/2004

Site Location:
Seksyen 3 Tambahan,
Bandar Baru Bangi
Selangor

Company (Owner):
Perbadanan Kemajuan Negeri Selangor
Pn Linda @ Lenny (Site Enginner) – 019 6088004
Faizal Azfar Bin Zulkiefle (Practical Student) – 012 9198551

Civil Works (Contractor):
AIRIS Engineering Sdn. Bhd.
Mr Saharuddin - 012 9719721

Attached to:
Pn Linda @ Lenny (Site Enginner) – 019 6088004

4.2.2 Production Rates Data Collected

The production rates for super structures data gathering was done by recording data using the direct observation of listed activities and photos taking at the sites. The works completed was recorded in the 'Production rate database record' sheets for one hour duration of time as shows in the figures 12345;

4.2.3 Analyzing Result Using Statistic

By using Basic Statistic method, all the production rates been analyzed to find he mean, maximum, minimum and variance value to be compared with the previous data.
Figure 12345 shows the result analysis.

4.2.4 Comparison of Result with Previous Research

Data collected is analyzed by using statistic for database. Final comparison between data obtained and published sources determine the outcomes of this project

The author compared the results with the data from previous researches. Mr Saiful, (FYP Coordinator for Dr Arazi) gave production rates made by him and previous students. The smaller the range of production rates for the activities, variance values are lower and that determine the reliability of the production rates to be used in this research.
Figure 12345 shows the Result Analysis.

No.	Activity	Standart	SELANGOR (Housing) ; day 1 - set 1	SELANGOR (Housing) ; day 1 - set 2	SELANGOR (Housing) ; day 2 - set 1	SELANGOR (Housing) ; day 2 - set 2	SELANGOR (Housing) ; day 3 - set 1	SELANGOR (Housing) ; day 3 - set 2	PERAK (Institution) ; day 1 - set 1	PERAK (Institution) ; day 1 - set 2	PERAK (Institution) ; day 2 - set 1	PERAK (Institution) ; day 2 - set 2	PERAK (Institution) ; day 3 - set 1	PERAK (Institution) ; day 3 - set 2	MELAKA (Sport Complex) ; day 1 - set 1	MELAKA (Sport Complex) ; day 1 - set 1	MELAKA (Sport Complex) ; day 1 - set 1	MELAKA (Sport Complex) ; day 1 - set 1	MELAKA (Sport Complex) ; day 1 - set 1	MELAKA (Sport Complex) ; day 1 - set 1
		session	morning	evening	morning	evening	morning	evening	morning	evening	morning	evening	morning	evening	morning	evening	morning	evening	morning	evening
	Superstructure																			
1																				
	1) Column (1st floor)																			
	a) Installing formwork and falsework	10 m³/hr	11.5 m³/hr	11.845 m³/hr	13 m³/hr	12.35 m³/hr	12.3 m³/hr	11.931 m³/hr	10.7 m³/hr	11.021 m³/hr	11.4 m³/hr	10.83 m³/hr	11.1 m³/hr	10.767 m³/hr	9 m³/hr	8.73 m³/hr	8 m³/hr	7.6 m³/hr	8.5 m³/hr	8.245 m³/hr
	b) Installing reinforcement in formwork	0.45 Ton/hr	0.518 Ton/hr	0.534 Ton/hr	0.585 Ton/hr	0.556 Ton/hr	0.553 Ton/hr	0.537 Ton/hr	0.482 Ton/hr	0.496 Ton/hr	0.513 Ton/hr	0.487 Ton/hr	0.499 Ton/hr	0.485 Ton/hr	0.405 Ton/hr	0.393 Ton/hr	0.36 Ton/hr	0.342 Ton/hr	0.383 Ton/hr	0.371 Ton/hr
	c) Concrete placement (skip&bucket / pumping chute	3.33 m³/hr	3.83 m³/hr	4.009m³/hr	4.329 m³/hr	4.113 m³/hr	4.096 m³/hr	3.973 m³/hr	3.563 m³/hr	3.67 m³/hr	3.796 m³/hr	3.606 m³/hr	3.969 m³/hr	3.585m³/hr	2.997 m³/hr	2.907m³/hr	2.664 m³/hr	2.531 m³/hr	2.831 m³/hr	2.746 m³/hr
	d) Dismantle formwork and falsework	18 m³/hr	20.7 m³/hr	21.321 m³/hr	23.4 m³/hr	22.23 m³/hr	22.14 m³/hr	21.476 m³/hr	19.26 m³/hr	19.838 m³/hr	20.52 m³/hr	19.494 m³/hr	19.98 m³/hr	19.381 m³/hr	16.2 m³/hr	15.714m³/hr	14.4 m³/hr	13.68 m³/hr	15.3 m³/hr	14.841 m³/hr
	2) Floor Beam (1st floor)																			
	a) Installing falsework	35 m³/hr	40.25 m³/hr	41.458 m³/hr	45.5 m³/hr	43.225 m³/hr	43.05 m³/hr	41.759 m³/hr	37.45 m³/hr	38.574 m³/hr	39.9 m³/hr	37.905 m³/hr	38.85 m³/hr	37.685 m³/hr	31.5 m³/hr	30.555 m³/hr	28 m³/hr	26.6 m³/hr	29.75 m³/hr	28.858 m³/hr
	b) Installing formwork	21 m³/hr	24.15 m³/hr	24.875 m³/hr	27.3 m³/hr	25.935 m³/hr	25.83 m³/hr	25.055 m³/hr	22.47 m³/hr	23.144 m³/hr	23.94m³/hr	22.743 m³/hr	23.31 m³/hr	22.611 m³/hr	18.9m³/hr	18.333 m³/hr	16.8 m³/hr	15.96 m³/hr	17.85 m³/hr	17.315 m³/hr
	c) Installing reinforcement in formwork	0.5 Ton/hr	0.575 Ton/hr	0.592 Ton/hr	0.65 Ton/hr	0.618 Ton/hr	0.615 Ton/hr	0.597 Ton/hr	0.535 Ton/hr	0.551 Ton/hr	0.57 Ton/hr	0.542 Ton/hr	0.555 Ton/hr	0.538 Ton/hr	0.45Ton/hr	0.437 Ton/hr	0.4 Ton/hr	0.38 Ton/hr	0.425 Ton/hr	0.413 Ton/hr
	d) Concrete placement (skip&bucket / pumping chute	7.5 m³/hr	8.625 m³/hr	8.884 m³/hr	9.75 m³/hr	9.263 m³/hr	9.225 m³/hr	8.948 m³/hr	8.025 m³/hr	8.266 m³/hr	8.55 m³/hr	8.123 m³/hr	8.325 m³/hr	8.075 m³/hr	6.75 m³/hr	6.5475m³/hr	6 m³/hr	5.7 m³/hr	6.375 m³/hr	6.184 m³/hr
	e) Dismantle formwork	26 m³/hr	29.90 m³/hr	30.797 m³/hr	33.8 m³/hr	32.11 m³/hr	31.98 m³/hr	31.021 m³/hr	27.82 m³/hr	28.655 m³/hr	29.64 m³/hr	28.158 m³/hr	28.86 m³/hr	27.994 m³/hr	23.4 m³/hr	22.698 m³/hr	20.8 m³/hr	19.76 m³/hr	22.1 m³/hr	21.437 m³/hr
	f) Dismantle falsework	39 m³/hr	44.85 m³/hr	46.196 m³/hr	50.7 m³/hr	48.165 m³/hr	47.97 m³/hr	46.531 m³/hr	41.73 m³/hr	42.982 m³/hr	44.46 m³/hr	42.237 m³/hr	43.29 m³/hr	41.991 m³/hr	35.1 m³/hr	34.047m³/hr	31.2 m³/hr	29.64 m³/hr	33.15 m³/hr	32.156 m³/hr
	3) Floor Slab (1st floor)																			
	a) Installing falsework	35 m³/hr	40.25 m³/hr	41.458 m³/hr	45.5 m³/hr	43.225 m³/hr	43.05 m³/hr	41.758 m³/hr	37.45 m³/hr	38.574 m³/hr	39.9 m³/hr	37.905 m³/hr	38.85 m³/hr	37.685 m³/hr	31.5 m³/hr	30.555 m³/hr	28 m³/hr	26.6 m³/hr	29.75 m³/hr	28.858 m³/hr
	b) Installing formwork	55 m³/hr	63.25 m³/hr	65.148 m³/hr	71.5 m³/hr	67.925 m³/hr	67.65 m³/hr	65.621 m³/hr	58.85 m³/hr	60.616 m³/hr	62.7 m³/hr	59.565 m³/hr	61.05 m³/hr	59.219 m³/hr	49.5 m³/hr	48.015 m³/hr	44 m³/hr	41.8 m³/hr	46.75 m³/hr	45.348 m³/hr
	c) Installing reinforcement in formwork	0.5 Ton/hr	0.483 Ton/hr	0.592 Ton/hr	0.65 Ton/hr	0.617 Ton/hr	0.615 Ton/hr	0.597 Ton/hr	0.535 Ton/hr	0.551Ton/hr	0.57 Ton/hr	0.542 Ton/hr	0.555 Ton/hr	0.538 Ton/hr	0.45Ton/hr	0.436Ton/hr	0.4 Ton/hr	0.38 Ton/hr	0.425 Ton/hr	0.413 Ton/hr
	d) Concrete placement (skip&bucket / pumping chute	13 m³/hr	14.95 m³/hr	15.399 m³/hr	16.9 m³/hr	16.055 m³/hr	15.99 m³/hr	15.51 m³/hr	13.91 m³/hr	14.327 m³/hr	14.82 m³/hr	14.079 m³/hr	14.43 m³/hr	13.997 m³/hr	11.7 m³/hr	11.349 m³/hr	10.4 m³/hr	9.88 m³/hr	11.05 m³/hr	11.155 m³/hr
	e) Dismantle formwork	57 m³/hr	65.55 m³/hr	67.517 m³/hr	74.1 m³/hr	70.395 m³/hr	70.11 m³/hr	68 m³/hr	60.99 m³/hr	62.82 m³/hr	64.98 m³/hr	61.731 m³/hr	63.27 m³/hr	61.372 m³/hr	51.3 m³/hr	49.761 m³/hr	45.6 m³/hr	43.32 m³/hr	48.45 m³/hr	46.997 m³/hr
	f) Dismantle falsework	39 m³/hr	44.85 m³/hr	46.196 m³/hr	50.7 m³/hr	48.165 m³/hr	47.97 m³/hr	46.531 m³/hr	41.73 m³/hr	42.982 m³/hr	44.46 m³/hr	42.237 m³/hr	43.29 m³/hr	41.991 m³/hr	35.1 m³/hr	34.047 m³/hr	31.2 m³/hr	29.64 m³/hr	33.15 m³/hr	32.155 m³/hr

Figure 1.1: Summary of all production rates data collected at sites (page 1 of 2)

No.	Activity	Standart	SELANGOR (Housing) ; day 1 - set 1	SELANGOR (Housing) ; day 1 - set 2	SELANGOR (Housing) ; day 2 - set 1	SELANGOR (Housing) ; day 2 - set 2	SELANGOR (Housing) ; day 3 - set 1	SELANGOR (Housing) ; day 3 - set 2	PERAK (Institution) ; day 1 - set 1	PERAK (Institution) ; day 1 - set 2	PERAK (Institution) ; day 2 - set 1	PERAK (Institution) ; day 2 - set 2	PERAK (Institution) ; day 3 - set 1	PERAK (Institution) ; day 3 - set 2	MELAKA (Sport Complex) ; day 1 - set 1	MELAKA (Sport Complex) ; day 1 - set 2	MELAKA (Sport Complex) ; day 2 - set 1	MELAKA (Sport Complex) ; day 2 - set 2	MELAKA (Sport Complex) ; day 3 - set 1	MELAKA (Sport Complex) ; day 3 - set 2
		session	morning	evening	morning	evening	morning	evening	morning	evening	morning	evening	morning	evening	morning	evening	morning	evening	morning	evening
2																				
	D) Column (mof floor)																			
	a) Installing formwork and falsework	9.5 m²/hr	10.93 m²/hr	11.256 m²/hr	12.35 m²/hr	11.733 m²/hr	11.685 m²/hr	11.334 m²/hr	10.165 m²/hr	10.48 m²/hr	10.83 m²/hr	10.289 m²/hr	10.545 m²/hr	10.229 m²/hr	8.55 m²/hr	8.294 m²/hr	8.55 m²/hr	7.22 m²/hr	8.075 m²/hr	7.833 m²/hr
	b) Installing reinforcement in formwork	0.4 Ton/hr	0.46 Ton/hr	0.474 Ton/hr	0.52 Ton/hr	0.494 Ton/hr	0.492 Ton/hr	0.477 Ton/hr	0.428 Ton/hr	0.44 Ton/hr	0.456 Ton/hr	0.433Ton/hr	0.444 Ton/hr	0.431 Ton/hr	0.36 Ton/hr	0.349 Ton/hr	0.36 Ton/hr	0.304 Ton/hr	0.34 Ton/hr	0.329 Ton/hr
	c) Concrete placement (skip&bucket / pumping chute	2.67 m³/hr	3.07 m³/hr	3.162 m³/hr	3.471 m³/hr	3.297 m³/hr	3.284 m³/hr	3.186 m³/hr	2.857 m³/hr	2.943 m³/hr	3.044 m³/hr	2.891 m³/hr	2.964 m³/hr	2.875 m³/hr	2.403 m³/hr	2.331 m³/hr	2.403 m³/hr	2.029 m³/hr	2.269 m³/hr	2.201 m³/hr
	d) Dismantle formwork and falsework	16 m²/hr	18.4 m²/hr	18.952 m²/hr	20.8 m²/hr	19.76 m²/hr	19.68 m²/hr	19.089 m²/hr	17.12 m²/hr	17.634 m²/hr	18.24 m²/hr	17.328 m²/hr	17.76 m²/hr	17.227 m²/hr	14.4 m²/hr	13.968 m²/hr	14.4 m²/hr	12.16 m²/hr	13.6 m²/hr	13.192 m²/hr
	E) Floor Beam (mof floor)																			
	a) Installing falsework	35 m²/hr	40.25 m²/hr	41.458 m²/hr	45.5 m²/hr	43.225 m²/hr	43.05 m²/hr	41.759 m²/hr	37.45 m²/hr	38.574 m²/hr	39.9 m²/hr	37.905 m²/hr	38.85 m²/hr	37.685 m²/hr	31.5 m²/hr	30.555 m²/hr	31.5 m²/hr	26.6 m²/hr	29.75 m²/hr	28.857m²/hr
	b) Installing formwork	23 m²/hr	26.45 m²/hr	27.243 m²/hr	29.9 m²/hr	28.405 m²/hr	28.29 m²/hr	27.441 m²/hr	24.61 m²/hr	25.348 m²/hr	26.22 m²/hr	24.909 m²/hr	25.53 m²/hr	24.764 m²/hr	20.7 m²/hr	20.079 m²/hr	20.7 m²/hr	17.48 m²/hr	19.55 m²/hr	18.964 m²/hr
	c) Installing reinforcement in formwork	0.38 Ton/hr	0.437 Ton/hr	0.450 Ton/hr	0.494 Ton/hr	0.467 Ton/hr	0.467 Ton/hr	0.453 Ton/hr	0.406 Ton/hr	0.419 Ton/hr	0.433 Ton/hr	0.412 Ton/hr	0.422 Ton/hr	0.409 Ton/hr	0.342 Ton/hr	0.332 Ton/hr	0.342 Ton/hr	1.289 Ton/hr	0.323 Ton/hr	0.313 Ton/hr
	d) Concrete placement (skip&bucket / pumping chute	5 m³/hr	5.75 m³/hr	5.923 m³/hr	6.5 m³/hr	6.175 m³/hr	6.15 m³/hr	5.966 m³/hr	5.35 m³/hr	5.511 m³/hr	5.7 m³/hr	5.415 m³/hr	5.55 m³/hr	5.384 m³/hr	4.5 m³/hr	4.365 m³/hr	4.5 m³/hr	3.8 m³/hr	4.25 m³/hr	4.122 m³/hr
	e) Dismantle formwork	29 m²/hr	33.35 m²/hr	34.351 m²/hr	37.7 m²/hr	35.815 m²/hr	35.67 m²/hr	34.501 m²/hr	31.03 m²/hr	31.961 m²/hr	33.06 m²/hr	31.407 m²/hr	32.19 m²/hr	31.224 m²/hr	26.1 m²/hr	25.317 m²/hr	26.1 m²/hr	22.04 m²/hr	24.65 m²/hr	23.911 m²/hr
	f) Dismantle falsework	38 m²/hr	43.7 m²/hr	45.011 m²/hr	49.4 m²/hr	46.93 m²/hr	46.74 m²/hr	45.238 m²/hr	40.66 m²/hr	41.88 m²/hr	43,32 m²/hr	41.154 m²/hr	42.18 m²/hr	40.915 m²/hr	34.2 m²/hr	33.174 m²/hr	34.2 m²/hr	28.88 m²/hr	32.3 m²/hr	31.331 m²/hr

Figure 1.2: Summary of all production rate data collected at sites (page 2 of 2)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	11.5 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.518 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	3.83 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
d) Dismantle formwork and falsework	20.7 m³/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	40.25 m³/hr		15			✓			✓		✓				✓		✓		✓						
b) Installing formwork	24.15 m³/hr		15			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.575 Ton/hr		12			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	8.625 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	29.90 m³/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	44.85 m³/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	40.25 m³/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	63.25 m³/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.483 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	14.95 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	65.55 m³/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	44.85 m³/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	10.93 m³/hr		12		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.46 Ton/hr		10		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	3.07 m³/hr		10		✓		✓			✓					✓			✓	✓				✓	✓	
d) Dismantle formwork and falsework	18.4 m³/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	40.25 m³/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	26.45 m³/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.437 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	5.75 m³/hr		10			✓	✓			✓					✓			✓	✓				✓	✓	
e) Dismantle formwork	33.35 m³/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	43.7 m³/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.1: Production rate record form (Selangor Site; day1 - set1)

Activity	Common	Alternative	No. of worker	Veather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	11.845 m³/hr		8			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.534 Ton/hr		5			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	4.009m³/hr		8			✓			✓		✓				✓		✓		✓			✓	✓		
d) Dismantle formwork and falsework	21.321 m³/hr		3		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	41.458 m³/hr		15			✓			✓		✓				✓		✓		✓						
b) Installing formwork	24.875 m³/hr		15			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.592 Ton/hr		12			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	8.884 m³/hr		10			✓			✓		✓				✓		✓		✓			✓	✓		
e) Dismantle formwork	30.797 m³/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	46.196 m³/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	41.458 m³/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	65.148 m³/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.592 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	15.399 m³/hr		10			✓			✓		✓				✓		✓		✓			✓	✓		
e) Dismantle formwork	67.517 m³/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	46.196 m³/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	11.256 m³/hr		12		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.474 Ton/hr		10		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	3.162 m³/hr		10		✓		✓			✓					✓			✓	✓			✓	✓		
d) Dismantle formwork and falsework	18.952 m³/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	41.458 m³/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	27.243 m³/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.450 Ton/hr		14		✓		✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	5.923 m³/hr		10			✓	✓			✓					✓			✓	✓			✓	✓		
e) Dismantle formwork	34.351 m³/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	45.011 m³/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.2: Production rate record form (Selangor Site; day1 – set2)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	13 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.585 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	4.329 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
d) Dismantle formwork and falsework	23.4 m³/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	45.5 m³/hr		15			✓			✓		✓				✓		✓		✓						
b) Installing formwork	27.3 m³/hr		15			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.65 Ton/hr		12			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	9.75 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	33.8 m³/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	50.7 m³/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	45.5 m³/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	71.5 m³/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.65 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	16.9 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	74.1 m³/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	50.7 m³/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	12.35 m³/hr		12		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.52 Ton/hr		10		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	3.471 m³/hr		10		✓		✓			✓					✓			✓	✓			✓		✓	
d) Dismantle formwork and falsework	20.8 m³/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	45.5 m³/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	29.9 m³/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.494 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	6.5 m³/hr		10			✓	✓			✓					✓			✓	✓			✓		✓	
e) Dismantle formwork	37.7 m³/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	49.4 m³/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.3: Production rate record form (Selangor Site; day2 – set1)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	12.35 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.556 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	4.113 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
d) Dismantle formwork and falsework	22.23 m³/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	43.225 m³/hr		15			✓			✓		✓				✓		✓		✓						
b) Installing formwork	25.935 m³/hr		15			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.618 Ton/hr		12			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	9.263 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	32.11 m³/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	48.165 m³/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	43.225 m³/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	67.925 m³/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.617 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	16.055 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	70.395 m³/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	48.165 m³/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	11.733 m³/hr		12		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.494 Ton/hr		10		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	3.297 m³/hr		10		✓		✓			✓					✓			✓	✓				✓	✓	
d) Dismantle formwork and falsework	19.76 m³/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	43.225 m³/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	28.405 m³/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.467 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	6.175 m³/hr		10			✓	✓			✓					✓			✓	✓				✓	✓	
e) Dismantle formwork	35.815 m³/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	46.93 m³/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.4: Production rate record form (Selangor Site; day2 – set2)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	12.3 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.553 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	4.096 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
d) Dismantle formwork and falsework	22.14 m³/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	43.05 m³/hr		15			✓			✓		✓				✓		✓		✓						
b) Installing formwork	25.83 m³/hr		15			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.615 Ton/hr		12			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	9.225 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	31.98 m³/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	47.97 m³/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	43.05 m³/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	67.65 m³/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.615 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	15.99 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	70.11 m³/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	47.97 m³/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	11.685 m³/hr		12		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.492 Ton/hr		10		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	3.284 m³/hr		10		✓		✓			✓					✓			✓	✓				✓	✓	
d) Dismantle formwork and falsework	19.68 m³/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	43.05 m³/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	28.29 m³/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.467 Ton/hr		14		✓		✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	6.15 m³/hr		10			✓	✓			✓					✓			✓	✓				✓	✓	
e) Dismantle formwork	35.67 m³/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	46.74 m³/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.5: Production rate record form (Selangor Site; day3 – set1)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	11.931 m²/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.537 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	3.973 m³/hr		10			✓			✓		✓				✓		✓		✓				✓		✓
d) Dismantle formwork and falsework	21.476 m²/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	41.759 m²/hr		15			✓			✓		✓				✓		✓		✓						
b) Installing formwork	25.055 m²/hr		15			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.597 Ton/hr		12			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	8.948 m³/hr		10			✓			✓		✓				✓		✓		✓				✓		✓
e) Dismantle formwork	31.021 m²/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	46.531 m²/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	41.758 m²/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	65.621 m²/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.597 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	15.51 m³/hr		10			✓			✓		✓				✓		✓		✓				✓		✓
e) Dismantle formwork	69 m²/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	46.531 m²/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	11.334 m²/hr		12		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.477 Ton/hr		10		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	3.186 m³/hr		10		✓		✓			✓					✓			✓	✓				✓		✓
d) Dismantle formwork and falsework	19.089 m²/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	41.759 m²/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	27.441 m²/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.453 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	5.966 m³/hr		10			✓	✓			✓					✓			✓	✓				✓		✓
e) Dismantle formwork	34.501 m²/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	45.338 m²/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.6: Production rate record form (Selangor Site; day3 – set2)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	10.7 m³/hr		6			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.482 Ton/hr		4			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	3.563 m³/hr		6			✓			✓		✓				✓		✓		✓				✓	✓	
d) Dismantle formwork and falsework	19.26 m³/hr		2		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	37.45 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing formwork	22.47 m³/hr		10			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.535 Ton/hr		9			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	8.025 m³/hr		7			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	27.82 m³/hr		6		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	41.73 m³/hr		6		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	37.45 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing formwork	58.85 m³/hr		10			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.535 Ton/hr		10			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	13.91 m³/hr		6			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	60.99 m³/hr		6		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	41.73 m³/hr		6		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	10.165 m³/hr		8		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.428 Ton/hr		6		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	2.857 m³/hr		6		✓		✓			✓					✓			✓	✓				✓	✓	
d) Dismantle formwork and falsework	17.12 m³/hr		6		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	37.45 m³/hr		10		✓		✓			✓					✓			✓	✓						
b) Installing formwork	24.61 m³/hr		10		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.406 Ton/hr		10			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	5.35 m³/hr		6			✓	✓			✓					✓			✓	✓				✓	✓	
e) Dismantle formwork	31.03 m³/hr		6			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	40.66 m³/hr		6			✓	✓			✓					✓			✓	✓						

Figure 2.7: Production rate record form (Perak; day1 – set1)

Activity	Common	Alternative	No. of worker	Veather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	11.021 m³/hr		6			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.496 Ton/hr		4			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	3.67 m³/hr		6			✓			✓		✓				✓		✓		✓				✓	✓	
d) Dismantle formwork and falsework	19.838 m³/hr		2		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	38.574 m³/hr		10		✓				✓		✓				✓		✓		✓						
b) Installing formwork	23.144 m³/hr		10		✓				✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.551 Ton/hr		9		✓				✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	8.266 m³/hr		7		✓				✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	28.655 m³/hr		6		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	42.982 m³/hr		6		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	38.574 m³/hr		10		✓				✓		✓				✓		✓		✓						
b) Installing formwork	60.616 m³/hr		10		✓				✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.551Ton/hr		10		✓				✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	14.327 m³/hr		6		✓				✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	62.82 m³/hr		6			✓			✓		✓				✓		✓		✓						
f) Dismantle falsework	42.982 m³/hr		6			✓			✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	10.48 m³/hr		8		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.44 Ton/hr		6		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	2.943 m³/hr		6		✓		✓			✓					✓			✓	✓				✓	✓	
d) Dismantle formwork and falsework	17.634 m³/hr		6		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	38.574 m³/hr		10			✓	✓			✓					✓			✓	✓						
b) Installing formwork	25.348 m³/hr		10			✓	✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.419 Ton/hr		10			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	5.511 m³/hr		6			✓	✓			✓					✓			✓	✓				✓	✓	
e) Dismantle formwork	31.961 m³/hr		6			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	41.88 m³/hr		6			✓	✓			✓					✓			✓	✓						

Figure 2.8: Production rate record form (Perak Site; day1 – set2)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	11.4 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.513 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	3.796 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
d) Dismantle formwork and falsework	20.52 m²/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	39.9 m²/hr		15			✓			✓		✓				✓		✓		✓						
b) Installing formwork	23.94m²/hr		15			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.57 Ton/hr		12			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	8.55 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	29.64 m²/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	44.46 m²/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	39.9 m²/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	62.7 m²/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.57 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	14.82 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	64.98 m²/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	44.46 m²/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	10.83 m²/hr		12		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.456 Ton/hr		10		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	3.044 m³/hr		10		✓		✓			✓					✓			✓	✓				✓	✓	
d) Dismantle formwork and falsework	18.24 m²/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	39.9 m²/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	26.22 m²/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.433 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	5.7 m³/hr		10			✓	✓			✓					✓			✓	✓				✓	✓	
e) Dismantle formwork	33.06 m²/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	43.32 m²/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.9: Production rate record form (Perak Site; day2 – set1)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	10.83 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.487 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	3.606 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
d) Dismantle formwork and falsework	19.494 m²/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	37.905 m²/hr		15			✓			✓		✓				✓		✓		✓						
b) Installing formwork	22.743 m²/hr		15			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.542 Ton/hr		12			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	8.123 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	28.158 m²/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	42.237 m²/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	37.905 m²/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	59.565 m³/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.542 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	14.079 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	61.731 m²/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	42.237 m²/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	10.289 m²/hr		12		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.433Ton/hr		10		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	2.891 m³/hr		10		✓		✓			✓					✓			✓	✓			✓		✓	
d) Dismantle formwork and falsework	17.328 m²/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	37.905 m²/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	24.909 m²/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.412 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	5.415 m³/hr		10			✓	✓			✓					✓			✓	✓			✓		✓	
e) Dismantle formwork	31.407 m²/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	41.154 m²/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.10: Production rate record form (Perak Site; day2 – set2)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	11.1 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.499 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	3.969 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
d) Dismantle formwork and falsework	19.98 m³/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	38.85 m³/hr		15			✓			✓		✓				✓		✓		✓						
b) Installing formwork	23.31 m³/hr		15			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.555 Ton/hr		12			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	8.325 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	28.86 m³/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	43.29 m³/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	38.85 m³/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	61.05 m³/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.555 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	14.43 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	63.27 m³/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	43.29 m³/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	10.545 m³/hr		12		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.444 Ton/hr		10		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	2.964 m³/hr		10		✓		✓			✓					✓			✓	✓			✓		✓	
d) Dismantle formwork and falsework	17.76 m³/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	38.85 m³/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	25.53 m³/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.422 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	5.55 m³/hr		10			✓	✓			✓					✓			✓	✓			✓		✓	
e) Dismantle formwork	32.19 m³/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	42.18 m³/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.11: Production rate record form (Perak Site; day3 – set1)

Activity	Common	Alternative	No. of worker	Veather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	10.767 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.485 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	3.585m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
d) Dismantle formwork and falsework	19.381 m³/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	37.685 m³/hr		15			✓			✓		✓				✓		✓		✓						
b) Installing formwork	22.611 m³/hr		15			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.538 Ton/hr		12			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	8.075 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	27.994 m³/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	41.991 m³/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	37.685 m³/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	59.219 m³/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.538 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	13.997 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	61.372 m³/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	41.991 m³/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	10.229 m³/hr		12		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.431 Ton/hr		10		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	2.875 m³/hr		10		✓		✓			✓					✓			✓	✓			✓		✓	
d) Dismantle formwork and falsework	17.227 m³/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	37.685 m³/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	24.764 m³/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.409 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	5.384 m³/hr		10			✓	✓			✓					✓			✓	✓			✓		✓	
e) Dismantle formwork	31.224 m³/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	40.915 m³/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.12: Production rate record form (Perak Site; day3 – set2)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	9 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.405 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	2.997 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
d) Dismantle formwork and falsework	16.2 m³/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	31.5 m³/hr		15		✓				✓		✓				✓		✓		✓						
b) Installing formwork	18.9m³/hr		15		✓				✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.45Ton/hr		12		✓				✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	6.75 m³/hr		10		✓				✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	23.4 m³/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	35.1 m³/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	31.5 m³/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	49.5 m³/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.45Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	11.7 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	51.3 m³/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	35.1 m³/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	8.55 m³/hr		12			✓	✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.36 Ton/hr		10			✓	✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	2.403 m³/hr		10			✓	✓			✓					✓			✓	✓			✓		✓	
d) Dismantle formwork and falsework	14.4 m³/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	31.5 m³/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	20.7 m³/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.342 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	4.5 m³/hr		10			✓	✓			✓					✓			✓	✓			✓		✓	
e) Dismantle formwork	26.1 m³/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	34.2 m³/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.13: Production rate record form (Perak Site; day1 – set1)

Activity	Common	Alternative	No. of worker	Weather			Availability			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	8.73 m²/hr		6			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.393 Ton/hr		4			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	2.907m³/hr		6			✓			✓		✓				✓		✓		✓				✓		
d) Dismantle formwork and falsework	15.714m²/hr		2		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	30.555 m²/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing formwork	18.333 m²/hr		10			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.437 Ton/hr		9			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	6.5475m³/hr		7			✓			✓		✓				✓		✓		✓				✓		
e) Dismantle formwork	22.698 m²/hr		6		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	34.047m²/hr		6		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	30.555 m²/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing formwork	48.015 m²/hr		10			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.436Ton/hr		10			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	11.349 m³/hr		6			✓			✓		✓				✓		✓		✓				✓		
e) Dismantle formwork	49.761 m²/hr		6		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	34.047 m²/hr		6		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	8.294 m²/hr		8		✓		✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.349 Ton/hr		6		✓		✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	2.331 m³/hr		6		✓		✓			✓					✓			✓	✓				✓		
d) Dismantle formwork and falsework	13.968 m²/hr		6		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	30.555 m²/hr		8		✓		✓			✓					✓			✓	✓						
b) Installing formwork	20.079 m²/hr		8		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.332 Ton/hr		8			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	4.365 m³/hr		5			✓	✓			✓					✓			✓	✓				✓		
e) Dismantle formwork	25.317 m²/hr		5			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	33.174 m²/hr		5			✓	✓			✓					✓			✓	✓						

Figure 2.14: Production rate record form (Melaka Site; day1 – set2)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	8 m²/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.36 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	2.664 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
d) Dismantle formwork and falsework	14.4 m²/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	28 m²/hr		15		✓				✓		✓				✓		✓		✓						
b) Installing formwork	16.8 m²/hr		15		✓				✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.4 Ton/hr		12		✓				✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	6 m³/hr		10		✓				✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	20.8 m²/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	31.2 m²/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	28 m²/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	44 m²/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.4 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	10.4 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	45.6 m²/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	31.2 m²/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	8.55 m²/hr		12			✓	✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.36 Ton/hr		10			✓	✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	2.403 m³/hr		10			✓	✓			✓					✓			✓	✓			✓		✓	
d) Dismantle formwork and falsework	14.4 m²/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	31.5 m²/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	20.7 m²/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.304 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	4.5 m³/hr		10			✓	✓			✓					✓			✓	✓			✓		✓	
e) Dismantle formwork	26.1 m²/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	34.2 m²/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.15: Production rate record form (Melaka Site; day2 – set1)

Activity	Common	Alternative	No. of worker	Veather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	10.83 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.487 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	3.606 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
d) Dismantle formwork and falsework	19.494 m³/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	37.905 m³/hr		15			✓			✓		✓				✓		✓		✓						
b) Installing formwork	22.743 m³/hr		15			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.542 Ton/hr		12			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	8.123 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	28.158 m³/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	42.237 m³/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	37.905 m³/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	59.565 m³/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.542 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	14.079 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	61.731 m³/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	42.237 m³/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	7.22 m³/hr		12			✓	✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.304 Ton/hr		10			✓	✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	2.092 m³/hr		10			✓	✓			✓					✓			✓	✓				✓	✓	
d) Dismantle formwork and falsework	12.16 m³/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	26.6 m³/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	17.48 m³/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.289 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	3.8 m³/hr		10			✓	✓			✓					✓			✓	✓				✓	✓	
e) Dismantle formwork	22.04 m³/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	28.88 m³/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.16: Production rate record form (Melaka Site; day2 – set2)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	8.5 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.383 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	2.831 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
d) Dismantle formwork and falsework	15.3 m³/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	29.75 m³/hr		15		✓				✓		✓				✓		✓		✓						
b) Installing formwork	17.85 m³/hr		15		✓				✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.425 Ton/hr		12		✓				✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	6.375 m³/hr		10		✓				✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	22.1 m³/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	33.15 m³/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	29.75 m³/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	46.75 m³/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.425 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	11.05 m³/hr		10			✓			✓		✓				✓		✓		✓				✓	✓	
e) Dismantle formwork	48.45 m³/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	33.15 m³/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	8.075 m³/hr		12			✓	✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.34 Ton/hr		10			✓	✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	2.269 m³/hr		10			✓	✓			✓					✓			✓	✓				✓	✓	
d) Dismantle formwork and falsework	13.6 m³/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	29.75 m³/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	19.55 m³/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.323 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	4.25 m³/hr		10			✓	✓			✓					✓			✓	✓				✓	✓	
e) Dismantle formwork	24.65 m³/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	32.3 m³/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.17: Production rate record form (Melaka Site; day3 – set1)

Activity	Common	Alternative	No. of worker	Weather			Avaiability of Material and Equipment			Location of the project			Site Supervision			Site Conditions			Project complexity			Machineries used per day			
	Unit	Unit		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Bh	C	V	Cm
Superstructure																									
1) Column (1st floor)																									
a) Installing formwork and falsework	8.245 m³/hr		10			✓			✓		✓				✓		✓		✓						
b) Installing reinforcement in formwork	0.371 Ton/hr		7			✓			✓		✓				✓		✓		✓						
c) Concrete placement (skip&bucket / pumping chute	2.746 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
d) Dismantle formwork and falsework	14.841 m³/hr		5		✓				✓		✓				✓		✓		✓						
2) Floor Beam (1st floor)																									
a) Installing falsework	28.858 m³/hr		15		✓				✓		✓				✓		✓		✓						
b) Installing formwork	17.315 m³/hr		15		✓				✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.413 Ton/hr		12		✓				✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	6.184 m³/hr		10		✓				✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	21.437 m³/hr		8		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	32.156 m³/hr		8		✓				✓		✓				✓		✓		✓						
3) Floor Slab (1st floor)																									
a) Installing falsework	28.858 m³/hr		14			✓			✓		✓				✓		✓		✓						
b) Installing formwork	45.348 m³/hr		14			✓			✓		✓				✓		✓		✓						
c) Installing reinforcement in formwork	0.413 Ton/hr		14			✓			✓		✓				✓		✓		✓						
d) Concrete placement (skip&bucket / pumping chute	11.155 m³/hr		10			✓			✓		✓				✓		✓		✓			✓		✓	
e) Dismantle formwork	46.997 m³/hr		10		✓				✓		✓				✓		✓		✓						
f) Dismantle falsework	32.155 m³/hr		10		✓				✓		✓				✓		✓		✓						
1) Column (roof floor)																									
a) Installing formwork and falsework	7.833 m³/hr		12			✓	✓			✓					✓			✓	✓						
b) Installing reinforcement in formwork	0.329 Ton/hr		10			✓	✓			✓					✓			✓	✓						
c) Concrete placement (skip&bucket / pumping chute	2.201 m³/hr		10			✓	✓			✓					✓			✓	✓			✓		✓	
d) Dismantle formwork and falsework	13.192 m³/hr		10		✓		✓			✓					✓			✓	✓						
2) Floor Beam (roof floor)																									
a) Installing falsework	28.857m³/hr		14		✓		✓			✓					✓			✓	✓						
b) Installing formwork	18.964 m³/hr		14		✓		✓			✓					✓			✓	✓						
c) Installing reinforcement in formwork	0.313 Ton/hr		14			✓	✓			✓					✓			✓	✓						
d) Concrete placement (skip&bucket / pumping chute	4.122 m³/hr		10			✓	✓			✓					✓			✓	✓			✓		✓	
e) Dismantle formwork	23.911 m³/hr		10			✓	✓			✓					✓			✓	✓						
f) Dismantle falsework	31.331 m³/hr		10			✓	✓			✓					✓			✓	✓						

Figure 2.18: Production rate record form (Melaka Site; day3 – set2)

No.	Activity	Unit Measurement	MEAN; Selangor site (Housing)	MEAN; Perak site (Institution)	MEAN; Melaka site (Sport Complex)		Previous Data	Mean $\overline{X}=\frac{\sum X_i}{11}$	Max	Min	Variance $s^2=[1/(n-1)]\sum_{i=1}^{n}(x_i-\overline{X})^2$
			3days - 6sets	3days - 6sets	3days - 6sets						
1	**Superstructure**										
	1) Column (1st floor)										
	a) Installing formwork and falsework	m³/hr	12.154	10.97	8.346		10	10.49	13	7.6	3.789
	b) Installing reinforcement in formwork	Ton/hr	0.547	0.494	0.376		0.45	0.472	0.585	0.342	0.008
	c) Concrete placement (skip&bucket / pumping chute	m³/hr	4.058	3.698	2.779		3.33	3.512	0.585	4.329	0.435
	d) Dismantle formwork and falsework	m³/hr	21.878	19.476	15.023		18	18.882	23.4	13.68	12.11
	2) Floor Beam (1st floor)										
	a) Installing falsework	m³/hr	42.54	38.294	29.21		35	36.715	45.5	26.6	46.367
	b) Installing formwork	m³/hr	25.254	23.036	17.526		21	22.029	27.3	15.96	15.846
	c) Installing reinforcement in formwork	Ton/hr	0.608	0.549	0.418		0.5	0.525	0.65	0.38	0.009
	d) Concrete placement (skip&bucket / pumping chute	m³/hr	9.116	8.227	6.259		7.5	9.75	5.7	7.868	2.138
	e) Dismantle formwork	m³/hr	31.601	28.521	21.699		26	27.274	33.8	19.76	25.679
	f) Dismantle falsework	m³/hr	47.402	42.782	32.549		39	40.911	50.7	29.64	57.778
	3) Floor Slab (1st floor)										
	a) Installing falsework	m³/hr	42.54	38.394	29.211		35	36.715	45.5	26.6	46.53
	b) Installing formwork	m³/hr	66.849	60.333	45.902		55	57.695	71.5	41.8	114.915
	c) Installing reinforcement in formwork	Ton/hr	0.592	0.549	0.417		0.5	0.519	0.65	0.38	0.008
	d) Concrete placement (skip&bucket / pumping chute	m³/hr	15.801	14.261	10.922		13	13.661	16.9	9.88	6.221
	e) Dismantle formwork	m³/hr	69.279	62.527	47.571		57	59.792	74.1	43.32	123.418
	f) Dismantle falsework	m³/hr	47.402	42.782	32.549		39	40.911	50.7	29.64	57.778
2											
	1) Column (roof floor)										
	a) Installing formwork and falsework	m³/hr	11.548	10.423	8.087		9.5	10.109	12.35	7.22	3.129
	b) Installing reinforcement in formwork	Ton/hr	0.486	0.439	0.34		0.4	0.422	0.52	0.304	0.006
	c) Concrete placement (skip&bucket / pumping chute	m³/hr	3.245	2.929	2.283		2.67	2.819	3.471	2.092	0.24
	d) Dismantle formwork and falsework	m³/hr	19.447	17.551	13.62		16	16.873	20.8	12.16	8.834
	2) Floor Beam (roof floor)										
	a) Installing falsework	m³/hr	42.54	38.394	29.794		35	36.909	45.5	26.6	42.268
	b) Installing formwork	m³/hr	27.955	25.23	19.579		23	24.255	29.9	17.48	18.253
	c) Installing reinforcement in formwork	Ton/hr	0.461	0.417	0.317		0.38	0.398	0.494	0.313	0.005
	d) Concrete placement (skip&bucket / pumping chute	m³/hr	6.077	5.845	4.256		5	5.273	6.5	3.8	1.004
	e) Dismantle formwork	m³/hr	35.231	31.812	24.686		29	30.577	37.7	22.04	28.944
	f) Dismantle falsework	m³/hr	46.187	41.358	32.348		38	39.964	49.4	28.88	49.336

Figure 3: Result Analysis (**Basis Statistics**)

4.3 Results Discussion

4.3.1 Job Analysis

Monitoring by direct productivity measurement provides these new management insights:

- Fast indication of factors that cause poor productivity.
- Continuous adjustment of manpower levels to actual, 'do-able' workload.
- Re-design of site logistics for smooth workflow and continuous improvement.
- Early warning of trends and opportunities that could impact budget or schedule.
- Customer-constructor relationship based on objective performance metrics.
- Capability to update estimating databases and planning future
- Estimate-independent productivity measurements.

Efficiency of labor utilization is a key measure of construction productivity. Direct productivity measurement provides management the valuable information needed to optimize productivity throughout project execution.

The Observation method of Job Analysis is suited for jobs in which the work behaviors are observable involving some degree of movement on the part of the incumbent, or job tasks are short in duration allowing for many observations to be made in a short period of time or a significant part of the job can be observed in a short period of time, or jobs in which the job analyst can learn information about the job through observation.

Advantages of Job Analysis

1) Obtain first-hand knowledge
2) See (and in some cases experience) the work environment
3) Support testimony

Disadvantages of Job Analysis

1) Presence of an observer may affect the incumbent
2) Involve significant amounts of time spent in concentration or mental effort.

4.3.1 General Assumption

General assumption made to arrive at direct manpower deployment;

- Latest estimated quantities from engineering disciplines for manpower calculation
- Manpower efficiency considered as per local conditions
- 48 hours working per week considered (6days a week for 8hours per day)
- Local holidays and festivals considered

4.3.2 Factors Affecting the Production Rate

Uncertainties identified regarding the lost of productivity due to;

Celebration

- During Ramadhan and festivals like Hari Raya, Deepavali, Christmas, New Year and Chinese New Year
- At Selangor site, the Lost Time Injury Free Man-hours celebration was conducted by PKNS HSE Department on 07/07/09. This was a one day event that reduce the daily progress

Weather

- Monsoon session between the month of November until January

  - Rain certainly was a factor with many hours being lost during the month. This is greater than the previous months added together. In week, hours were lost alone.

  - During the seven days of direct observation at Melaka site, weather during the month was unstable with a maximum temperature of 31.8□C and a minimum of 23.9□C. 4 hours of work lost due to rainfall.

Manpower

- Manpower shortage on construction

  - Additional man-hours required to complete and increase workforce

Health and Safety (HSE) Issues

- Incident / Accident

At Perak site, two incidents involved the 1st Aid case were reported for this reporting period.

- Staff lacerated hand against toolbox.
- Staff caught finger between pipe spools while rigging @ "Hoist" – Unsafe Act (Poor body position)

Equipment Damage

- Scaffold material fell from elevated position (unsuitable lifting device used) – Unsafe Act.
- Motor vehicle damaged – Struck by "load" in construction vehicle – Unsafe Act (Vehicle overloaded, load extending beyond load bin).

- Routine (weekly) audits have been conducted by the respective Area Managers. The audit scores appear naturally high in certain instances however certain trends are consistent
- PPE compliance remains poor (especially in regards to eye and hand protection), this trend is evident both amongst the labour force and supervisory levels on site.
- Access / aggress to and from elevated working platforms is a long standing concern. This has been compounded by poor stacking and storage practices in elevated positions, poor cable management and the unauthorized modification of scaffolds and working platforms.
- Several concerns pertaining to scaffolds and scaffolds work platforms have been identified namely; poor stacking and storage of material on scaffold platforms and unauthorized scaffold modifications.

Construction Acceleration

- Site modification

- Further delays in handover of foundation (due to site condition and others)

- Other Activities

- Heavy lift activities or more urgent need to complete underground works.

- Delay in piping and structural steel fabrication.

- Housekeeping

- The workers need to do housekeeping every morning before starting the work because of safety factors.

- Equipment and Raw Materials

- Erratic delivery of equipment and raw materials such as concrete.

- Different opinion about work fronts for civil and steel structures between Site Engineer & Contractor.

Initiative taken to mitigate delays and accelerate schedule;

Further following action plan has been established to closely monitor and maintain the progress in the subsequent working time;

- Effective Site Supervision

  - Establish direct manpower reporting on basic or calculate efficiencies for performances and reschedule manpower development as required mobilization of key managerial personnel to manage, coordinate and drive the work progress and ensuring supervision is at the work front not in meetings

- Hiring Qualified and Skill Manpower

  - Mobilizing manpower to site from market. There is one suggestion at the Melaka site to add on one more sub-contractor for erection works.

  - Improving the ratio of cutting and bending reinforcement and installing reinforcement in formwork for structure erection.

- More Productive Working Hours by;

  - Removing tea breaks, enforcing strict working times, implement night shift working, overtime shifts and apply incentive scheme.

Working hours

Workmen entry by: 07.30 hrs

Working hours: 08.00 hrs – 18.30 hrs

Tea break 1: 10.00 hrs - 10.30 hrs

Tea break 2: 15.30 hrs - 16.00 hrs

Lunch break: 12.30 hrs – 13.30 hrs

- Continue extended hours working up to 21.00 hrs for certain disciplines (internal erection, and civil works)

- Restricted operating hours for canteen

-installation of gate and fencing around canteen to restrict workmen entry during productive hours

- Close monitoring and increased expediting of raw material sourcing and manufacturing progress
- Concerted drive to identify and eliminate unsafe acts to be conducted, Working at heights awareness sessions, planned for DOSH visit, HSE Compliance audits to be conducted on all Subcontractors by Consortium Construction Partners.
- Bridge communication gap, all area managers along with their dedicated team shall operate from their site locations

  - Walkie talkie to all area managers and discipline supervisors

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CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Relevancy to the Objective

During the site observation, it has been observed that while some labour work for 8 hours, some labour work more / less due to the reasons like carrying the material before hand, leaving work earlier, and so on. From these findings, it has been concluded that, for the observations to be realistic, documentation should take the average of the working duration of each labour equally.

The site experience for formwork and steelwork has shown that it usually is not practically possible to measure the quantity of work done or quantity of materials used during 'one day' observations. Duration of an observation has to be calculated when the measured amount of material (i.e. formwork, steel) is completely used.

In a nut shell, the author can conclude that;

- ❑ This project provide useful, (near) real-time information about the process
- ❑ In selecting the three building case projects, the criteria are;
  - (1) Using traditional concrete construction method
  - (2) Multi-storey building
  - (3) Projects cost more than RM2million
- ❑ The data collected and data analyzed are reliable because the readings of each activity at different sites have not much difference.
- ❑ Superstructure activities are the repeated stage in construction, therefore the data obtained from the three sites are almost the same.

5.2 Recommendations

Several things can be done in order to improve this project;

- Need to explain to contractor that the publication of particular activity only for research purpose, no confidential information is being published.
- Discuss earlier with the site manager so that the safety officer assigned is able to accompany observer during the whole observation period.

CHAPTER 6

ECONOMIC BENEFIT ANALYSIS

6.1 Project Cost

Since this research is not a product based, not much expense is allocated for equipments and project materials. However, expenses are more towards the cost travelling and accommodations depending on the Construction Site location. Briefly, the nature of the project is to collect data from a large scope in such a way that the resultant production rate produce is relevant and can be use as a guideline by contractors or developers regardless of the site location and the scope of the project.

Direct observation at sites that had been done is located quite far from UTP. Take for example below are the expenses for the data collection been done in Daerah Kinta, Perak, Daerah Melaka Tengah, Melaka and Bandar Baru Bangi, Selangor.

Table 6.1.1: Expenses during collecting data

Travell Expenses			
Destination (2 way)	Mode	1 way Rate	3 Sets of Reading
IPOH-KINTA	Car	RM10	RM60
IPOH-KL	LRT	RM20	RM120
KL-MELAKA	Bus	RM25	RM150
Accommodation Expenses			
Destination	Rate per night	Duration	3 Sets of Reading
KL	RM50	3 days	RM150
Total Cost			
Travell Expenses	RM330		
Accommodation Expenses	RM150		
TOTAL COST	RM480		

For materials needed, not much expense needed because most of the materials are provided by the Construction Company during the site visit for example the Schedule of work, Detail Drawing Plans, Method of Statement and Project Scope.

For time recording the authors manage to record the time by using stop watch application which is provided in mobile phones.

From the table above it the cost of travelling and accommodation is obviously higher compare to other expenses. Therefore, the author had planned his journey to find more low cost travel alternatives and avoid high rate hotels for accommodation.

6.2 Business Elements and Economic Values

The purpose of the direct observation for construction works is to become 'generally familiar' with the progress and quality of the work and to determine if the work is being done in a manner that will yield results consistent with the contract documents.

The research indicated that the direct observation in the field is in the nature of a periodic examination or viewing of the work in process or completed as contrasted to the contractor's continuous superintendence and supervision of the trade workers and artisans involved in the day-to-day execution of the work.

By developing this database of Superstructure works, contractors can ensure that they already planned well for their works and they can know their cost for certain activity depending on their production rate values. The Management should be observing, evaluating, and reporting, whereas the contractor is controlling and directing the work.

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1. CIDB. Raising Singapore's construction productivity. CIDB Construction Productivity Taskforce Report, Construction Industry Development Board, Singapore, 1992.
2. M.M. Kumaraswamy and D.W.M. Chan. Determinants of construction duration. Journal of Construction Management and Economics, 1995, pp. 209–217.
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7. Kiziltas, S., and Akinci, B. (2008). "An Automated Approach for Generating Integrated Model-based Representations of Construction Project Histories" 12th International conference on Computing in Civil and Building Engineering (ICCCBE-XII), Beijing, China, October 16-18, 2008

Development of Production Rate Database by Direct Observation

Project : _____

Site Location : _____

_____

Company (Owner) : _____

Civil Works (Contractor) : _____

Observer : _____

Attached to : _____

Figure 4.5: Project Details Form

Additional Information:

Figure 4.6: Additional Information Form

Figure5.1: Project briefing from Site Manager

Figure 5.2: Briefing on the activities

Figure 5.3: Ground Beam

Figure 5.4: Ground Floor Slab

Figure 5.5: $1^{st}/2^{nd}/3^{rd}$ Floor Slab

Figure 5.6: Concrete placement

Figure 5.7: 1st/2nd/3rd Beam

Figure 5.8: Completed structures

Figure 5.9: Selangor Site (Housing)

Figure 5.10: Front view

Figure 5.11: Formwork

Figure 5.12: Raw reinforcement bars

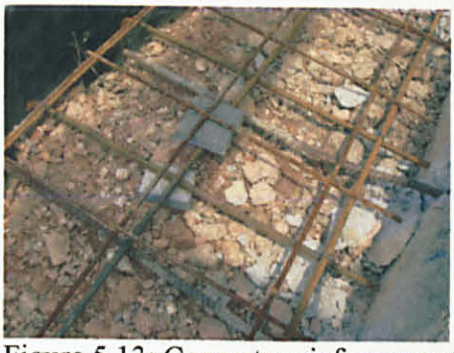

Figure 5.13: Concrete reinforcement

Figure 5.14: Concrete strength gaining

Figure 5.15: Melaka Site (Sport Complex)

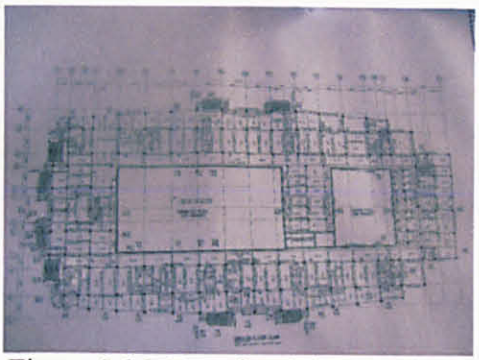

Figure 5.16: Drawing (Plan)

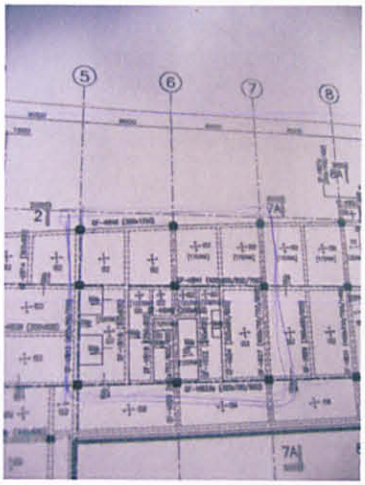

Figure 5.17: Drawing (Area measured)

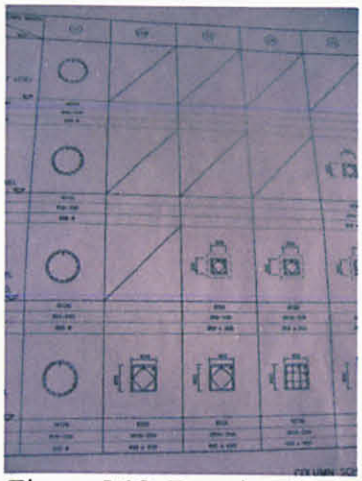

Figure 5.18: Drawing (Column)

Figure 5.19: Perak Site (Institution)

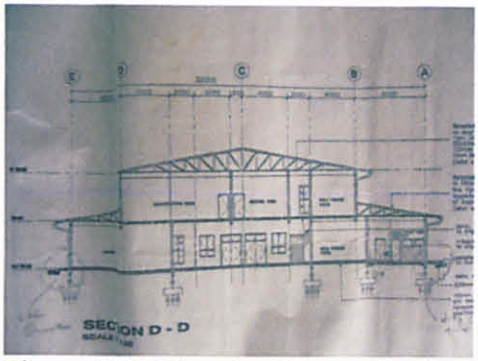

Figure 5.20: Drawing (Front view)

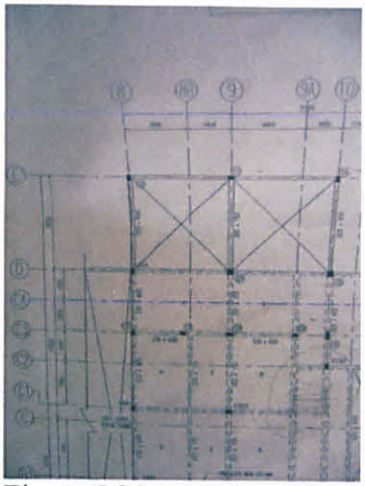

Figure 5.21: Drawing (Area measured)

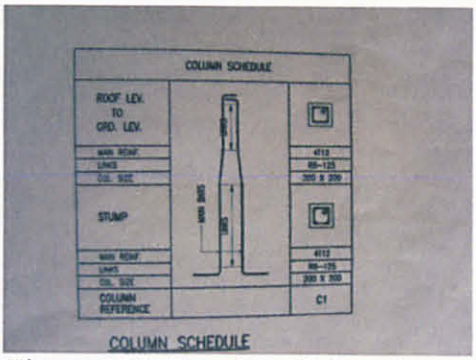

Figure 5.22: Drawing (Column)

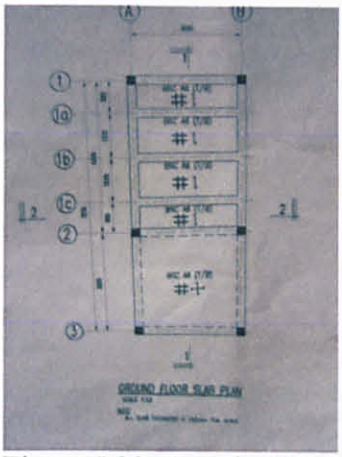

Figure 5.23: Drawing (Slab)